

cells in each gram of soil sampled to a depth of 3 inches, i.e. the algal cells which are concentrated in the top few millimetres of soil because light can penetrate only to this depth (Tchan and Whitehouse, 1953) have been mixed throughout the entire sample. According to the records in Table 1, there appears to be no correlation whatsoever between habitat and the occurrence of algae. For example, algae are present in some timbered areas, absent in others; on some scalds, but not on others. It is highly probable that in this changeable and extreme climate, population numbers fluctuate tremendously.

The most favourable habitat for algae in semi-arid climates appears to be on the under-surface of quartz pebbles which are light in colour. Dark-coloured pebbles lack algae on their under-surfaces. Light-coloured pebbles occur commonly on the treeless plains (gibber country), and in some of the mulga scrub on the ridges. The light-coloured or white quartz allows the light to penetrate, and at the same time, since the stones are partly buried, the water régime underneath is more favourable for algal growth than that on the exposed soil surface. Furthermore, during the night when air temperature drops, the under-surface of the pebble would act as a condensation apparatus. Similar growths have been recorded in U.S.A. by Williams (1943), who describes an accumulation of peat up to a thickness of $\frac{1}{4}$ inch (pebble peat) under stones.

A survey of the light-coloured pebbles showed that both size of stone and depth of burial are important as far as algal population is concerned. In all size classes pebbles which do not touch the surface or which merely rest on the surface support few algae. Those whose lower surfaces are in contact with the soil, and particularly when slightly buried, support the most algae. Size also is important, the larger the stone, the greater the algal population when the under-surface is in contact with or buried in the soil (Table 2).

TABLE 2.

Percentage Algal-cover on the Under-surface of Light-coloured Stones. Data Collected at Fowler's Gap in the Mulga Scrub (Rocky Ridge).

Diameter of Stones.	Number Examined.	Percentage of Stones with			
		0-10% Algal Cover.	11-30% Algal Cover.	About 50% Algal Cover.	80-100% Algal Cover.
0.5-1.0 cm.	480	37.4	8.4	12.5	41.7
1.0-1.5 cm.	580	20.0	17.1	24.0	37.9
3.0-3.5 cm.	120	0	16.7	16.7	66.6

In the area of stony country investigated at Fowler's Gap it was estimated that one-third to one-half of the stones are white (in some areas all stones are white, in others white stones are lacking), and that these white stones cover about one-sixth of the soil surface. (See Text-fig. 1.) Since half of the stone surface is algal-covered, about one-twelfth of the soil is covered by algae.

By incubating in Allison and Hoover's N-free medium, a positive culture of blue-green algae was obtained. In most cases species of *Nostoc* were predominant, in a few cases species of *Anabaena*. Other algae (members of the Chlorophyceae) occur if non-selective media containing combined nitrogen are used (the algal flora of part of the area has been listed in Moewus, 1952). By subculturing, colonies of the blue-greens free from *Azotobacter* and *Clostridium* were obtained, and these cultures fixed nitrogen under laboratory conditions.

DISCUSSION AND CONCLUSIONS.

The low frequency of *Azotobacter* (less than 50 cells per gram of soil) on the ranges supporting mulga scrub, and the apparent lack of *Azotobacter* from the sandy soils of the stable dunes (except the mallee) suggest that these organisms contribute

little to the nitrogen capital of the soil. In the most favourable habitat (in pockets of soil among rocks on the stony ridges) a population of 50 cells per gram with optimum external conditions could fix a maximum of 0.1 pound of nitrogen per acre per annum. (The calculation is similar to Jensen's (1950).) In the field, where general conditions are never optimum, the actual fixation is therefore insignificant.

This conclusion is in agreement with the findings of other workers, both in Australia and America. Jensen (1940), for example, reports similar low numbers of *Azotobacter* cells for the wheat belt in New South Wales, where ecological conditions are more favourable for the growth and activity of *Azotobacter* than in the semi-arid soils. He draws the general conclusion that for the wheat soils, *Azotobacter* fixes an inconsequential amount of nitrogen. For the Sydney district where moisture, temperature



Text-fig. 1.—Showing the distribution and sizes of wind-polished quartz pebbles lying on desert loam soil at Fowler's Gap, north of Broken Hill. The tracks running across the photo have been made by sheep travelling to and from a nearby watering place.

and soil organic matter, but not soil nutrients, are more favourable for *Azotobacter*, populations of 6,000–1,000 cells per gram have been recorded (Jensen, 1940; Tchan, 1953). Even at this much higher frequency this organism is still not regarded as being a significant contributor. Similar conclusions have been drawn for the semi-arid soils of the United States. Vandecaveye and Moodie (quoted by Russell, 1950) have found that the *Azotobacter* population is invariably low, and also that it may be apparently absent for some years and then become common again.

The presence of *Azotobacter* in the semi-arid country indicates, at least, that the organisms are capable of living under the present conditions, though there is little doubt that they merely exist. The contribution to the nitrogen capital made by algae is possibly higher than that made by *Azotobacter*. The algae are perhaps the more widespread, and since their cells are the larger, their contribution may be of greater

significance, particularly when localized colonies develop, as under pebbles. Using these pebbled areas to obtain a maximum value, we compute the following: It is estimated that 1,000 algal cells per gram of soil fixing nitrogen actively for 40 days in the year would add to the soil 1 lb. of nitrogen per acre. Since the highest concentrations of algae are of the order of 2,000-3,000 cells per gram, the theoretical maximum annual increment is 2-3 lb. per acre.

The total theoretical annual increment of nitrogen fixed by *Azotobacter* and N-fixing algae is, therefore, of the order of 3 lb., if both groups of organisms fixed to their maximum in the same area. This figure takes no account of denitrification, which may be active. This figure, as the following calculation will show, is too small to be detected by the Kjeldahl technique. The amount of nitrogen in the surface 6 inches of a soil with 1% organic carbon (0.1% N.) is about 2,000 lb. per acre. The Kjeldahl technique has an accuracy of about 2%. Consequently, the experimental error (which involves a possible error of ± 40 lb. N. per acre) is far higher than the theoretical maximum increment of N. contributed by the organisms under investigation. For this reason N. increment studies for these organisms cannot be done on a yearly basis; indeed, if the organisms are fixing nitrogen as calculated a period of some forty years would be required to give a contribution in excess of the Kjeldahl error.

As a general conclusion the following statement may be made: Under the existing conditions the non-symbiotic organisms fix nitrogen at a very slow rate; indeed in some areas the annual increment to the nitrogen capital must approach zero, for example, in badly eroded areas where the soil organic matter is extremely low and where moisture and temperature conditions are such that both bacteria and algae would either be absent or active for insignificant periods of time.

As far as the activity of the organisms in the virgin communities is concerned no reliable quantitative data can be presented because today no community is virgin. However, since accelerated erosion has greatly decreased organic levels and at the same time has intensified the severity of the adverse climatic conditions, we may assume that the activity of the nitrogen-fixing organisms in virgin areas could be higher than the rates quoted above. Nevertheless, even if we double the already generous estimate a very low annual increment still results. Whether this small annual addition accumulating over decades or even centuries accounts for the whole of the nitrogen capital in the community cannot yet be stated, nor can the relative importance of the non-symbiotic organisms in comparison with the symbiotic organisms or the addition of fixed nitrogen in rainfall be assessed until further research is done. These other sources of nitrogen will be discussed in subsequent papers.

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NOTES ON AUSTRALASIAN SIMULIIDAE (DIPTERA). IV.

By M. J. MACKERRAS and I. M. MACKERRAS, Queensland Institute of Medical Research,
Brisbane.

(Twenty-three Text-figures.)

[Read 25th May, 1955.]

Synopsis.

Two new species are described, *Simulium torrestanum* n. sp. from Badu in the Torres Straits, and *Austrosimulium magnum* n. sp. from North Queensland. New distribution recorded includes *Simulium ornatipes* Sk. from New Caledonia and two species from Flinders Is. in Bass Strait.

The material here recorded, including two interesting new species, has been accumulated since Part III of this series was published (These PROCEEDINGS, 77: 104-113, 1952).

Genus CNEPHIA End.

CNEPHIA STRENUA M. & M.

New distribution.—Queensland: Little Crystal Ck., 45 m. N. of Townsville, 1,100 ft., November-December; Elabana Falls, Lamington Plateau, South Queensland, 2,600 ft., December. Previously known only from the type locality near Cairns.

CNEPHIA AURANTIACUM (Tonn.).

New distribution.—Bass Strait: Mt. Strzelecki, Flinders Is., January (Mykytowycz). The larvae and pupae show some divergence from mainland and Tasmanian specimens, and may represent a distinct race.

CNEPHIA TONNOIRI ORIENTALIS M. & M.

New distribution.—South Australia: Myponga Ck., September; Sellick's Hill, October; Scott's Bottom, September; Brownhill Ck., September (all coll. Lines). Not previously known from that State. The localities lie on the peninsula south of Adelaide, and it is interesting that all the pupae examined belong to the eastern race, and not to the typical race which seems to be confined to the south-western corner of Western Australia.

CNEPHIA UMBRATORUM (Tonn.).

New distribution.—Victoria: Gould, September (Douglas); McKenzie Falls, Marysville, September (Neboiss); King Parrott Ck., Kinglake West, October (Neboiss); Boho, nr. Benalla, August (Douglas). Previously known only from Fern Tree Gully, Beaconsfield, Narbethong and Buxton in the same State.

CNEPHIA TEREBRANS (Tonn.).

New distribution.—Victoria: Bacchus Marsh, October; McKenzie and Turret Falls, Marysville, September; Middle Ck., Beaufort, October (all coll. Neboiss). A.C.T.: Black Mt., in light trap, September (Dyce). Previously known only from Sassafras in Victoria and Mt. Canobolas in New South Wales.

The records from the light trap set up by Mr. Dyce on the roof of the C.S.I.R.O. laboratory at Canberra are the first of their kind in this country. In addition to a female *C. terebrans*, the collections included a male *C. tonnoiri orientalis*, female *Austrosimulium cornutum*, and series of *A. furiosum*, *A. victoriae* and *A. bancrofti*.

CNEPHIA FERGUSONI (Tonn.).

New distribution.—Victoria: Cohuna, September (Read); Turret Falls, Marysville, September (Neboiss). Not previously recorded from the State.

Genus *SIMULIUM* Latr.*SIMULIUM ORNATIPES* Sk.

New distribution.—New Caledonia: Doutho R., east coast, May (Dumbleton). Previously known from New Guinea and the mainland of Australia. Many new records from Victoria show it to be widely distributed in that State (previously listed only from Merbein, Beechworth, Glen Rowan and Bacchus Marsh).

SIMULIUM AUREONIGRUM M. & M.

New distribution.—Queensland: Little Crystal Ck., 45 m. N. of Townsville, November-December. Previously known only from the type locality near Cairns.

SIMULIUM INORNATUM M. & M.

New distribution.—Victoria: Boho, nr. Benalla, August (Douglas). Previously known from south Queensland and eastern New South Wales.

SIMULIUM MELATUM Wh.

New distribution.—Victoria: Lavington Ck., nr. Albury, October (Myers); Ovens R., Bright, March (Myers); Harry's Ck., Violet Town (Douglas); Spring Ck., Bacchus Marsh, October (Neboiss); Boolarra, August (Douglas); Hiawatha, May, August (Douglas); Grieg's Ck., Yarram, January (Douglas). Previously recorded in the State only from Yarrowonga and Beechworth.

SIMULIUM TORRESIANUM, n. sp.

Types.—Holotype ♀, allotype ♂, morphotype larva and pupa, from small, clear creek on Badu Is., Torres Straits, April, in Division of Entomology, C.S.I.R.O., Canberra, A.C.T.

Distinctive Features.

Belongs to the *clathrinum* group, characterized by the presence of a pre-alar zone of pale, scale-like hairs on the pleura.

A small, dark species, 2.5 mm. long, with silvery hairs on scutum, and the pale zone on hind metatarsus somewhat obscure.

♀: Rather like *S. inornatum*, but distinguished from all Australian members of the group by the bare, rather shiny sixth to eighth abdominal tergites, and almost complete absence of pale hairs on the abdomen, there being only small patches at the sides of the third and fourth tergites.

♂: Distinguished by the upper facets of the eyes being remarkably enlarged, the fifth and subsequent tergites of the abdomen largely bare and shining, and the free margin of the anterior part of the phallosome strongly convex. *Pupa*: Respiratory filaments six, much longer than in *S. nicholsoni* and *S. faheyi*, and their mode of branching different. *Larva*: Resembles *S. aureonigrum* in having compound rectal gills, well developed ventral papillae, and lateral dark scales anterior to the cirlet; but the head pattern and gill-spot are quite different.

This species could be *S. oculatum* (End.), which was described from the Huon Gulf in New Guinea, and which also has greatly enlarged upper facets in the male and a similar abdominal pattern. The hairs on the scutum, however, are said to be golden, and the claws without teeth. *S. oculatum* cannot be recognized with any certainty until its group characters and early stages are known, so it seems best to treat our form as distinct.

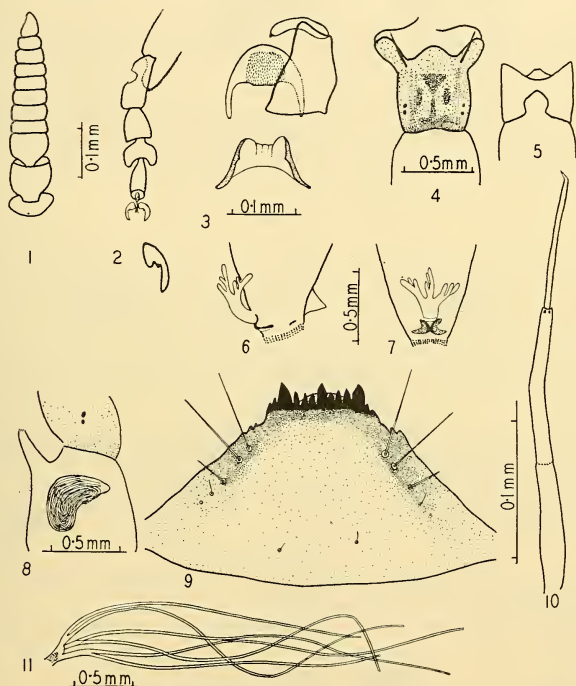
Female.

Head. Frons tapering towards antennae, about one-sixth of head width at narrowest point, dark greyish-brown, with sparse creamy-white hairs. Face similar. Antennae (Text-fig. 1) short; basal two segments brownish-yellow; remainder dark greyish-brown, with silvery tomentum. Proboscis and palpi dark brown.

Thorax. Scutum dark greyish-brown, with sparse silvery hairs which are denser posteriorly (specimen rubbed). Scutellum dark brown, with long, dark, bristly hairs. Postscutellum bare. Pleurae dark greyish-brown, with silvery scales on the pre-alar area. Legs dark brown, with brown and black hairs; basal four-fifths of hind metatarsus

rather obscurely pale. Calcipala well developed; claws with minute sub-basal tooth (Text-fig. 2). Wings clear, veins brown; halteres with brown stem and brownish-cream knob.

Abdomen brownish-black. First segment pale medially, with brown fringe. Second to fifth tergites with dark brown tomentum and short brown hairs; sixth to eighth bare, dark greyish-brown, shining rather dully, and with inconspicuous hairs; there is a small, almost linear patch of creamy-white hairs laterally near the posterior margins of the third and fourth tergites. Venter dull.



Text-figs. 1-11.—*Simulium torresianum*, n. sp.

1, antenna of female; 2, hind tarsus and claw of female; 3, hypopygium of male, the posterior part of the phallosome shown separately below; 4, 5, head of larva; 6, 7, posterior end of larva; 8, gill-spot; 9, submentum; 10, antenna; 11, respiratory horn of pupa.

Male.

Head. Eyes contiguous, upper eye-facets very greatly enlarged, up to 0.050 mm. in diameter, in 10-12 rows. Antennae slender; basal two segments yellowish-brown, remainder dark brown. Face dark greyish-brown, with white hairs. Proboscis and palpi dark greyish-brown.

Thorax. As in female; scutum covered with long silvery hairs. Legs and wings as in female, but veins and stem of halteres paler.

Abdomen. First tergite dark brown, with dark brown fringe; second and third tergites covered with black tomentum and brown hairs; fourth and subsequent tergites with median patch of blackish tomentum bearing bright brown hairs, large on fourth and decreasing in size on more apical segments, and with the remainder of the tergites

shining greyish-black, with black hairs. Venter black. This abdominal pattern is distinctive among the males of the Australian species of the group. Hypopygium as in other members of the group, except that the anterior part of the phallosome bulges posteriorly (Text-fig. 3), much as in *S. peregrinum*.

Cocoon.

Length 3 mm. Coarsely woven; anterior border rather irregular, with only an indication of a central dorsal projection; no collar.

Pupa.

Length 2.5-3 mm. Head and thorax ornamented with microscopic semilunar or triangular projections. Hairs long and fine. Abdominal chaetotaxy similar to that of other Australian members of the genus.

Respiratory organ (Text-fig. 11) consists of a very short stem, ornamented with minute spines, and giving off three main branches, each of which divides again close to the main stem, so that there are six very long, delicate filaments on each side. The tips of all those measured had been broken off, but some still measured 3.2 mm., so that the intact filaments must be as long as or longer than the body.

Larva.

Length, 5.5-6 mm. Greyish-brown, mottled. Head pale; pattern on dorsum very variable, usually of a cruciate type (Text-fig. 4). Antennae normal (Text-fig. 10). Ventral incisure deep (Text-fig. 5). Submentum with 13 teeth (Text-fig. 9).

Gill-spot large, roughly triangular, with broadly rounded angles; the antero-ventral angle is nearly a right angle, and the opposite side is indented (Text-fig. 8). The long, delicate filaments sweep down and round posteriorly; they do not continue to coil spirally, but after making one complete circle they double back rather sharply upon themselves. One or more of the slender tips may sometimes be seen projecting above the indentation.

Rectal gills compound, each with two or three branches. There is a brown patch or streak laterally anterior to the cirlet, as in *S. aureonigrum* and related species. Anal sclerite not particularly large, and of the usual X-shape (Text-fig. 7). Ventral papillae large (Text-fig. 6). Posterior cirlet with about nine or ten spines per row, the rows quite widely spaced.

Biology.

Larvae and pupae were found on dead twigs in a small, clear, rather sluggish creek with a sandy bottom. Habits of adults unknown.

Distribution.—Known only from the type locality on the island of Badu in the Torres Straits.

Genus AUSTROSIMULIUM Tonn.

AUSTROSIMULIUM MONTANUM M. & M.

New distribution.—Victoria: Boho, nr. Benalla, August (Douglas); Rocky Valley Ck., Bogong High Plains, January (Fennessy); Christmas Hills, nr. Melbourne, September (Douglas); Greig's Creek, Yarrum, September (Douglas); Wilson's Promontory, January, March (Douglas). Previously known in that State only from Sassafras, Narbethong and Buxton.

AUSTROSIMULIUM VICTORIAE (Roub.).

New distribution.—Bass Strait: Mt. Strzelecki, Flinders Is., January (Mykytowycz). Larvae only were collected. It would be interesting to know whether pupae on the island have cocoons of the mainland or Tasmanian type.

AUSTROSIMULIUM TORRENTIUM Tonn.

New distribution.—Victoria: Ovens R., Bright, March (Myers); Livingston Ck., Omeo, December (McMillan). Not previously recorded from that State. *A. torrentium* var. was found at both localities, *A. torrentium hilli* only at Bright.